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Request for grant of a patent

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The Patent Office

Cardiff Road
Newport
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NP10 8QQ

1. Your reference — C860/H

2. Patent application number *(The Patent Office will fill in this part)* — 0221512.7 — 17 SEP 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   John Herbert NORTH
   21 Briar Court
   Guardian Road
   Norwich
   NR5 8PR

   Patents ADP number *(if you know it)* — 7482763001

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — Improved separation apparatus

5. Name of your agent *(if you have one)* — Keith W Nash & Co

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   90-92 Regent Street
   Cambridge
   CB2 1DP

   Patents ADP number *(if you know it)* — 1206001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
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Claim(s)	
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
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11. I/We request the grant of a patent on the basis of this application.

Signature Date 16/09/2002

Keith W Nash & Co., Agents

12. Name and daytime telephone number of person to contact in the United Kingdom — Keith Nash 01223 355477

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C860/H

Title: Improved separation apparatus

Field of invention

This invention concerns apparatus using centrifugal force for separating material based on density.

Background to the invention

Whilst conventionally the technique is employed for separating dust and dirt particles from air, the technique is equally applicable to separating one fluid from another such as a liquid from a gas (or air) or one gas from another of different density.

GB Patent Specification 2,367,774 describes a multi-cyclone separation apparatus primarily designed to separate dust and dirt particles from an incoming airstream. One of the cyclone separation zones is contained within chambers 40 and 38, and in Fig 3 the transition from the cylindrical vortex starting chamber 40 to the frusto-conical chamber 38 is effected by a shallow intermediate frusto-conical section 64, having a different cone angle from that of the chamber 38. The reduction in radius of the helical airflow as it progresses down 38 accelerates the airflow in the cyclone as it continues to rotate around and down this section. After exiting therefrom the more dense material separates therefrom and remains in the dust-collecting chamber within the valve seating 80 above the valve closure 74.

The sudden lack of constraint on the airflow (and particularly on higher density content thereof) immediately below the opening at the lower end of cyclone chamber 38, results in a very efficient separation of the higher density content from the lower density content of the air leaving 38. Cyclonic inversion occurs as the rotating air interacts inter alia with the

cup 78, which results in a tightly circulating and upwardly rising helical airflow axially through the lower open end of 38 to travel upwardly and exit through openings 62 in the wall of central vortex-starter tube 58, to pass to the suction producing device 10 (typically a motor driven fan) via a filter 16.

The intermediate section 64 was originally proposed to smooth the transition between the two chambers 40 and 38. However, following experimental work on separators employing such intermediate sections it has become evident that the intermediate frusto-conical transition section has other advantages not hitherto appreciated, and the present invention identifies these alternative uses for an intermediate frusto-conical transition region between these two chambers.

Summary of invention

According to one aspect of the present invention in a cyclonic separation apparatus comprising a cylindrical vortex-starting chamber and frusto-conical main cyclonic separation chamber, an intermediate frusto-conical region is provided at the entrance to the main frusto-conical cyclone chamber for the purpose of reducing the overall axial length of the two chambers, thereby enabling a cyclonic separating vacuum cleaner to be built of reduced overall height for a given separation efficiency.

In particular the use of an intermediate frusto-conical region such as 64 has allowed the overall height of the two chambers (38, 40) making up the second cyclone separation stage of a two-stage cyclone separator, to be reduced.

A similar height reduction could be obtained if the lower end of chamber 40 is flat and perpendicular to the axis of 40 around the entrance to the frusto-conical chamber 38, but the turbulence created by such an arrangement dramatically reduces the separation efficiency of the cyclone system relative to what has been found when using an intermediate frusto-conical region between the cylindrical vortex-starting chamber and the main frusto-conical cyclonic separation chamber.

Experiments have also revealed that for a range of cone angles for the intermediate frusto-conical region, the separation efficiency is greater than if the main lower frusto-conical region were to be continued upwardly at the same cone angle, until its diameter corresponds to that of chamber 40 (thereby obviating any intermediate transition of any form) as in Fig 18 of GB 2,367,774 or in the separator shown in Figs 1 and 2 of EP 0042723, or Fig 5 of GB 2,321,181. Therefore not only is the overall height of the two chambers 38, 40 significantly increased if no intermediate frusto-conical transition section is employed, but the separation efficiency of the unit has been found to be less than that of a unit having an intermediate frusto-conical transition section 64.

According to a second aspect of the present invention in a cyclonic separation apparatus comprising a cylindrical vortex starting chamber and frusto-conical main cyclonic separating chamber, the transition between the cylindrical vortex starting chamber and the main frusto-conical cyclone defining separation chamber is located in the region of the downstream end of a central tubular member which extends axially of the vortex starting chamber, and is formed by an intermediate frusto-conical region having a larger cone-angle than that of the main cyclone chamber.

With reference to Fig 3 of GB 2,367,774, by locating the intermediate frusto-conical wall section 64 in the region of the apertured lower end of the central vortex starting tubular housing 58, a rapid reduction in radius is forced on the descending helical airflow which is accompanied by a corresponding rapid increase in rotational velocity in the region of the exit apertures 62 and just before it enters the conventional longer cyclone section 38.

A more rapid increase in rotational velocity near the apertures 62 in the end of tube 58 has been found to more successfully retain higher density content in the rotating airflow as it transfers to the main cyclone chamber 38, than if no such intermediate frusto-conical section is employed, as in the embodiment of Fig 18 of GB 2,367,774. This means less chance of higher density material migrating radially inwardly to exit via the apertures 62 instead of remaining in the airstream and travelling therein to the far end of the main

cyclone chamber 38 to be separated from the airflow and left in the collection zone, beyond 38.

This improvement has become even more noticeable when employing the apparatus to separate liquid from an incoming airstream.

In a preferred embodiment the half cone angle of the main frusto-conical section of the cyclone separator is in the range 8° to 14°, preferably 10° to 12°, while that of the intermediate frusto-conical section of the separator is in the range 20° to 40°, preferably 32° to 34°.

Two particularly preferred combinations of half-cone angles are 34° and 10°, and 32° and 12° respectively.

According to a third aspect of the present invention by incorporating an intermediate frusto-conical section between a cylindrical vortex starting chamber and a main frusto-conical cyclone chamber, thereby reducing the overall axial length of the two chambers, the main cyclone chamber can be mounted so as to extend to a lesser axial extent into a main dust collecting bin than would otherwise be the case, without increasing the combined axial length of the two chambers and the bin, thereby effectively increasing the volume of the bin available for storing dust and dirt, for a given combined axial length.

Where the apparatus is adapted to separate liquid from air, it is very advantageous to provide the maximum volume for collecting liquid in the bin (in place of dirt and dust particles) and as mentioned above the intermediate frusto-conical region provided for the purpose of increasing this volume is also found to improve the separation of water droplets from the airstream in the second cyclone set up by the cylindrical starter chamber and which thereafter helically rotates axially through the main cyclone chamber.

<u>Definition of cone angle</u>

In general the present invention only relates to shapes which are regular cones or frustums of regular cones.

If a regular cone is cut to reveal a triangular section, the cone angle is the angle between the two converging sides of the triangular cross-section which intersect at the apex of the cone. The axis of the regular cone bisects the cone angle, and each half of the cone angle is referred to herein as a half-cone angle. The cone angle of a frusto-conical shape is the cone angle of the regular cone which would be formed if the frusto-conical shape is continued to form a cone.

Results of experiments

Experiments have been undertaken using apparatus employing an intermediate frusto-conical region such as shown in Fig 3 of GB 2,367,774, in which the internal diameter of the cylindrical chamber 40 is 65mm, the half-cone angle of the intermediate frusto-conical section is 34°, and that of the longer main section 38 is 10°, the diameter of the smaller open end of the main section 38 is 18mm, and a gap of the order of 7 to 8mm is provided between the 18mm diameter opening and the plate 78 (see Fig 4 of GB 2,367,774).

With an airflow rate of 41-42 litres per second at inlet 14, between 0.5 and 1gm of Kaolin was found in the final filter from a 200gm charge of Kaolin introduced into the airflow. Typically 190-191 grams of Kaolin was found in the dust-collecting bin and between 8 and 9 grams in the cyclone system after the experiments.

In the case of 1 litre of water introduced into the airstream at the dirty air inlet such as 14 of Fig 3 of GB 2,367,774, with a similar air flow in the range 41-42 litres per second, the weight of water not collected in the bin at the end of the experiment (i.e. lost during separation) was of the order of 0.02gm. This equates to the evaporative loss expected from the mixing of 1 litre of water at room temperature with an airflow of 41-42 litres of air per second at the same temperature.